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The habitat concept and a plea for standard terminology

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Abstract We compared the uses and definitions of habitat-related terms in 50 articles from 1980 to 1994 to operational definitions we derived from the literature. Only 9 (18%) of the articles we reviewed defined and used habitat-related terms consistently and according to our definitions of the terms. Forty-seven articles used the term "habitat;" however, it was only defined and used consistent with our definition in 5 articles (11%) and was confused with vegetation association or defined incompletely in 42 papers (89%). "Habitat type" was the term most commonly used incorrectly; 16 of 17 times (94%) it was used to indicate vegetation association, but habitat and vegetation association are not synonymous. Authors did not provide definitions for habitat use, selection, preference, or availability 23 of 28 times (82%). We concluded that habitat terminology was used vaguely in 82% of the articles we reviewed. This distorts our communication with scientists in other disciplines and alienates the public because we give ambiguous, indefinite, and unstandardized answers to ecological questions in public and legal situations. Scientists should define and use habitat terminology operationally, so that the concepts are measurable and accurate. We must take the challenge to standardize terminology seriously, so that we can make meaningful statements to advance science.

Key words availability, critical habitat, habitat type, operational terminology, preference, quality, selection, standardization

Block and Brennan (1993) discussed the concept of habitat in the context of ornithology, stating that it could be considered one of the few unifying theories in contemporary ecology. Their opinion was based on a wide survey of papers that related the presence, abundance, distribution, and diversity of birds to aspects of their environments, and in which habitat was invoked to explain the factors and processes that contributed to the evolutionary history and fitness of animals. Other authors have likewise emphasized the importance of wildlife-habitat relationships. Specifically, "habitat use" by wildlife has been addressed by numerous researchers (Verner et al. 1986, Morrison et al. 1992, Bookhout 1994). However, we think there are several problems with current studies and discussions of habitat use that are the source of ambiguities and inaccuracies.

First, although several authors have recommended that studies of wildlife-habitat relationships be placed in the proper spatial and temporal scales (Wiens 1981, Morrison et al. 1992, Block and Brennan 1993, Litvaitis et al. 1994), this has yet to happen. Researchers need to recognize that their perceptions of wildlife-habitat relationships are scale-dependent, reflecting the different scales at which different animals operate and at which they operate (Wiens 1989). Johnson (1980) and Hutto (1985), for example, proposed that animals select habitat through a hierarchical spatial scaling process, with selection occurring first at the level of the geographic range; second, at the level where animals conduct their activities (i.e., in their home ranges); third, at the level of specific sites or for specific components within their home ranges; and fourth, according to how they will procure resources

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within these micro-sites. Hutto (1985) proposed that selection at the level of the geographic range is probably genetically determined, and Wecker (1964) and Wiens (1972) demonstrated that selection at finer levels (i.e., smaller scales) may be influenced by learning and experience and so is directed more intentionally by individual animals. Thus, wildlife-habitat relationships are distinctly different at different levels, and authors of habitat papers need to be sure they specify the levels to which their studies are applicable, and not extrapolate their data beyond those levels.

In terms of temporal scale, authors should be specific about when their studies were undertaken, and to what time period(s) the studies apply. Morrison et al. (1992:163–164) stated that too many researchers ignore temporal variation in resource use, or sample from narrow time periods in which the resulting wildlife-habitat relationships apply only minimally to other situations. Conversely, researchers commonly sample from across broad time periods (i.e., years; summer or winter seasons) and then use averaged values for variables across the periods, potentially masking differences in resource use.

The second issue that authors of habitat papers should consider is that if we want to advance wildlife ecology, we must be sure that the fundamental concepts with which we work are well defined, and hence, well understood. This facilitates discussion among ecologists by forcing us to use words specifically instead of loosely, but it also facilitates better public communication, minimizing confusion and ambiguity. Peters (1991) urged that environmental scientists "operationalize" ecological concepts. Peters (1991:76) argued that definitions of concepts such as habitat should be operational, i.e., practical, measurable specifications of the ranges of the specific phenomena the terms represent. The definitions may change over time, but if the concepts are to be scientifically useful, then the original and subsequent definitions must be measurable so that they can be applied consistently.

The third problem we see in discussions of habitat, and one that underlies all of the issues we have outlined above, is that the use of habitat terminology is imprecise and ambiguous. Block and Brennan (1993) stated that specific definitions of the term "habitat" are often vague, ranging in scope from how species are associated with broad, landscape-scale vegetation to very detailed descriptions of the immediate physical environments used by species. We recognize a similar tendency among papers in wildlife science and think that the vagueness and variability is nonproductive because it detracts from the ability to communicate effectively about habitat-related subjects.

Many other papers have called for the development of standard definitions of ecological terms (Romesburg 1981, McCoy and Bell 1991, Morrison et al. 1992:11, Weckerly 1992). However, based on the variable usage and application of such terms observed in even a cursory search of the literature, it appears that the call has not been heeded. Inconsistent definitions lead ecologists to a variety of approaches for measuring the terms (e.g., habitat use, selection, preference; carrying capacity; Wiens 1984:398), making it difficult to conduct inter- and intra-disciplinary comparisons. The looseness of our ecological definitions has even contributed to prolonged court battles (e.g., definitions of "old-growth forests" in the Pacific Northwest; Murphy and Noon 1991, Orians 1993). Murphy and Noon (1991) stated that the terms "habitat" and "critical" have never been defined precisely and independently, and that this has led to difficulties in determining exactly what critical habitat is for federally listed species. Because standard definitions are rarely used, some authors have thrown up their hands at ever trying to provide them (Verner et al. 1986:*xi*). We think, however, that the ubiquitous use of the word "habitat" in the wildlife, restoration ecology, and conservation biology literature, and the prevalence of words related to habitat (e.g., community, ecosystem, and biodiversity) creates an urgent need for standard definitions at this time.

To address some of the problems we see with definitions of habitat, we present information on the current and common uses and misuses of these terms. We also suggest standard definitions to encourage wildlife biologists (and others) to define and use the words less haphazardly.

Methods

To evaluate how recent (i.e., 1980–1994) authors have used habitat-related terms, we reviewed 50 papers from prominent journals and books in the wildlife and ecology fields that discussed wildlife-habitat relationships (Table 1). Papers and books were selected based on (1) their importance as current wildlife publications (e.g., the Wildlife Techniques Manuals, fourth and fifth editions [Schemnitz 1980, Bookhout 1994]), and (2) their discussion of mammalian-habitat relationships. Block and Brennan (1993) recently provided a review of avian-habitat relationships. We then recorded all uses in the papers of terms relating to habitat, including habitat type; habitat use, selection, preference, or availability; habitat quality; micro- and macrohabitat; critical habitat; and nonhabitat (Table 2).

In our reviews of each paper we noted if habitat terms were defined, and evaluated the definition(s),

Table 1. Sources of literature reviewed (journals, books, symposium proceedings, and reports) for wildlife habitat-related terminology.

Reference sources	No. selections reviewed in source
Books and dictionaries	
Allaby (1992)	1
Bell et al. (1991)	1
Fowler and Smith (1981)	1
Patton (1992)	1
Peek (1986)	1
Journals and series	
Conservation Biology	2
Ecological Applications	2
Ecological Monographs	1
Ecology	2
Environmental Management	2
Journal of Mammalogy	7
Journal of Wildlife Management	7
Research and Management Techniques for Wildlife and Habitats, Fifth ed.	6
Southwestern Naturalist	1
Wildlife Management Techniques Manual, Fourth ed.	2
Wildlife Society Bulletin	2
Symposium and forum proceedings	
Rodiek and Bolen (1991)	2
Verner et al. (1986)	3
Wilson and Peter (1988)	1
Agency publications	
Brown (1994)	1
Cooperrider et al. (1986)	1
Morrison et al. (1991)	1
Ockenfels et al. (1991)	1
U.S. Department of Agriculture (1992)	1

if given. We also looked for inconsistent uses of words within a paper and recorded different uses of each term. To determine if the definitions were "correct," "incorrect," "weak," or "poor," we compared them to standard definitions we developed based on definitions presented by Morrison et al. (1992) and Block and Brennan (1993), which were in turn drawn from ecologists such as Grinnell (1917), Leopold (1933), Hutchinson (1957), Daubenmire (1968), and Odum (1971). We therefore define "habitat" as the resources and conditions present in an area that produce occupancy—including survival and reproduction—by a given organism. Habitat is organism-specific; it relates the presence of a species, population, or individual (animal or plant) to an area's physical and biological characteristics. Habitat implies more than vegetation or vegetation structure; it is the sum of the specific resources that are needed by organisms. Wherever an organism is provided with resources that allow it to survive, that is habitat. Thus, migration and dispersal corridors and the land that animals occupy during breeding and nonbreeding seasons are habitat. Habitat is therefore *not* equivalent to "habitat type," a term coined by Daubenmire (1968:27-32), which refers only to the type of vegetation association in an area or to the potential of vegetation to reach a specified climax stage. "Habitat" is much more than the vegetation (e.g., pine [*Pinus*]-oak [*Quercus*] woodland) in an area, and so we think the term "habitat type" should not be used when discussing wildlife-habitat relationships. When authors intend to refer only to the vegetation that an animal uses, they should use "vegetation association" or "vegetation type" instead.

We define the term "habitat use" as the way an animal uses (or "consumes," in a generic sense) a collection of physical and biological components (i.e., resources) in a habitat. "Habitat selection," as defined by Hutto (1985:458), is a hierarchical *process* involving a series of innate and learned behavioral decisions made by an animal about what habitat it would use at different scales of the environment. Johnson (1980) similarly defined selection as the process by which an animal chooses which habitat components to use. Given the body of literature that treats selection as a process, we also define selection this way, and furthermore, we define habitat "preference" as the consequence of the process, resulting in the disproportional use of some resources over others.

"Habitat availability" refers to the accessibility and procurability of physical and biological components of a habitat by animals. This is in contrast to the "abundance" of these resources, which refers only to their quantity in the habitat, irrespective of the organisms present (Wiens 1984:402). In theory, one should be able to measure the amounts and kinds of resources available to animals; in practice, however, it is not necessarily possible to assess resource availability from an animal's point of view (Litvaitis et al. 1994). For example, we can measure the abundance (by trapping) of a prey species for a particular predator, but we cannot say that all of the prey present in the habitat are available to the predator because there may be factors that restrict their accessibility, such as presence of ample cover. Similarly, Morrison et al. (1992:139) proposed that vegetation beyond the reach of an animal is unavailable for it to feed on, even though the vegetation may be "preferred" forage. Although measuring actual resource availability is important for understanding wildlife-habitat relationships, in practice it is seldom measured because of the difficulty of determining exactly what is available and what is not (Wiens 1984:406). Conse-

Table 2. Ratings of 50 papers reviewed for their definitions and consistencies in use of habitat-related terms, as compared to our standard definitions of the concepts. A rating of 1 = a term was defined similarly to our definition and was used consistently throughout the article; 2 = no definition, or an incomplete one, was provided for a term, but the use of the term was similar to our use; 3 = no definition for a term was given, or the use of the term fluctuated between being correct and incorrect in the article; and 4 = neither of the criteria under "1" was met.

Reference	Term used	Rating	Reason
Adam et al. 1994	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat type	4	Confused with vegetation association
Allaby 1992	Habitat	1	
Alverson et al. 1988	Habitat	4	No definition; confused with vegetation association
	Habitat type	4	No definition; confused with vegetation association
	Unfavorable habitat	3	Implies "unsuitable" habitat
Anderson and Gutzwiller 1994	Habitat	2	Incomplete definition
Bellantoni and Krausman 1993	Habitat	2	No definition; use acceptable
	Habitat use	2	No definition; use acceptable
	Habitat availability	2	Only defined through statistics
Bissonette et al. 1991	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat preference	2	No definition; use acceptable
Boitani et al. 1994	Habitat	4	Confused with vegetation association
	Habitat type	4	Confused with vegetation association
Boyd et al. 1986	Habitat	3	Gave definition; sometimes confused with vegetation association
	Habitat types	4	Confused with vegetation association
	Habitat preference	2	No definition; use acceptable
	Habitat selection	2	No definition; use acceptable
	Habitat suitability	2	No definition; use questionable
	Habitat quality	2	No definition; use questionable
	Critical habitat	2	No definition; use acceptable
Brown 1994	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat selection	2	Only defined through statistics
Brown et al. 1994	Habitat	3	No definition; sometimes confused with substrate association
	Habitat use	2	No definition; use acceptable
	Habitat selection	2	No definition; use questionable
	Micro/macrohabitat	2	No definition; use acceptable
Bryant 1991	Habitat	4	Confused with vegetation association
Burkett and Thompson 1994	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat use	2	No definition; use acceptable
	Suitable habitat	3	Should not use; implies there is unsuitable habitat
Butynski 1990	Habitat type	4	Confused with vegetation association
Clark et al. 1993	Habitat	2	No definition; use acceptable
	Habitat selection	1	
	Habitat quality	1	
	Suitable habitat	3	Should not use; implies there is unsuitable habitat
	"Unused" habitat	1	Use appropriate in this case
Debinski and Brussard 1994	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat type	4	Confused with vegetation association
Etchberger et al. 1989	Habitat	2	No definition; use acceptable
	Habitat use	2	No definition; use acceptable
	Abandoned habitat	1	Use appropriate in this case
Fleming 1991	Habitat	4	Confused with vegetation association
	Habitat use	2	No definition; use acceptable
Fowler and Smith 1981	Habitat	2	No definition; use acceptable
Frank and McNaughton 1992	Habitat	4	No definition; confused with vegetation association
	Habitat preference	2	No definition; use acceptable
Franklin and Johnson 1994	Habitat	4	Confused with vegetation association
	Habitat type	4	Confused with vegetation association
Goldsmith 1990	Habitat	4	No definition; confused with vegetation association
Gould and Jenkins 1993	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat types	4	Confused with vegetation association
	Habitat selection	2	Only defined through statistics
	Habitat use	2	Only defined through statistics
Gysel and Lyon 1980:305–307	Habitat	1	
	Habitat type	1	Used according to Daubenmire's (1968) definition
Irwin et al. 1993	Habitat	2	No definition; use acceptable
Jaksic et al. 1990	Habitat	2	No definition; use acceptable
Kie et al. 1994	Habitat	2	No definition; use acceptable
	Habitat quality	2	No definition; use acceptable

Table 2. *(continued)* Ratings of 50 papers reviewed for their definitions and consistencies in use of habitat-related terms, as compared to our standard definitions of the concepts. A rating of 1 = a term was defined similarly to our definition and was used consistently throughout the article; 2 = no definition, or an incomplete one, was provided for a term, but the use of the term was similar to our use; 3 = no definition for a term was given, or the use of the term fluctuated between being correct and incorrect in the article; and 4 = neither of the criteria under "1" was met.

Reference	Term used	Rating	Reason
Kissell and Kennedy 1992	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat utilization	2	No definition; used acceptable
	Habitat type	4	Confused with vegetation association
Koehler and Hornocker 1991	Habitat	2	No definition; use acceptable
	Habitat use	2	No definition; use acceptable
	Habitat type	4	Confused with vegetation association
Kondolf 1994	Habitat	3	No definition; sometimes confused with vegetation association
Laymon and Barrett 1986	Habitat	2	No definition; use acceptable
	Habitat suitability	3	No definition; use questionable
Litvaitis et al. 1994	Habitat	1	
	Habitat use	1	
	Habitat selection	1	
	Habitat preference	1	
Mannan et al. 1994	Habitat	2	No definition; use acceptable
McCoy and Bell 1991	Habitat	3	No definition; said it was too difficult to define
	Habitat structure	3	Provided poor definition; not species-specific
	Habitat type	4	Confusing meaning
Morrison et al. 1991	Habitat	1	
	Habitat use	1	
	Habitat selection	2	No definition; use acceptable
Morrison et al. 1994	Habitat	3	No definition; sometimes confused with vegetation association
Murphy 1988	Natural habitat	2	No definition; use acceptable
	Microhabitat	4	Confused with vegetation association
Ockenfels et al. 1991	Habitat	4	Confused with vegetation association
	Habitat type	4	Confused with vegetation association
	Habitat selection	2	Only defined through statistics
	Suitable habitat	3	Should not use; implies there is unsuitable habitat
	"Less desirable" habitat	3	No definition; statement not supported
Patton 1992:43–44	Habitat	1	
Pauley et al. 1993	Habitat	2	No definition; use acceptable
	Habitat type	4	Confused with vegetation association
	Habitat use	2	Only defined through statistics used
	Habitat selection	2	Only defined through statistics used
Peek 1986:2,82	Habitat	2	Incomplete definition
	Habitat selection	2	Incomplete definition
	Habitat preference	1	
	Habitat use	1	
Plumb and Dodd 1993	Habitat use	2	No definition; use acceptable
	Habitat selection	2	No definition; use acceptable
Rosenberg and Raphael 1986	Habitat	2	No definition; use acceptable
Samuel and Fuller 1994	Habitat	2	Incomplete definition
Smith and Mannan 1994	Habitat	2	No definition; use acceptable
Spowart and Samson 1986	Habitat	3	Incomplete definition; sometimes confused with vegetation association
	Habitat type	4	Confused with vegetation association
	Habitat preference	2	No definition; use acceptable
	Habitat selection	2	No definition; use questionable
	Optimum habitat	4	No definition; is based on density of animals
	Availability of habitat	2	No definition; use acceptable
Tershy 1992	Habitat	3	No definition; sometimes confused with landscape properties
U.S. Department of Agriculture 1992	Habitat	2	No definition; use acceptable
	Occupied habitat	1	Use appropriate in this case
	Suitable habitat	3	Should not use; implies there is unsuitable habitat
	High value habitat	2	No definition; use questionable
White and Ralls 1993	Habitat type	4	Confused with landscape properties
Wielgus and Bunnell 1994	Habitat	3	No definition; sometimes confused with vegetation association
	Habitat type	4	Confused with vegetation association
	Habitat use	2	No definition; use acceptable
Yoakum et al. 1980	Habitat	2	No definition; use acceptable
	Quality habitat	2	No definition; use questionable

quently, the quantification of availability usually consists of *a priori* or *a posteriori* measures of the abundance of resources in an area used by an animal, rather than the availability. Thus, we think that in most instances the term "availability" should be avoided by biologists and the term "abundance" should be used instead because that is what is commonly measured. In situations where the accessibility of a resource has been determined for an animal, then analyses to determine habitat preference by comparing "use" versus "availability" are useful and operational.

We think that "habitat quality" refers to the ability of the environment to provide conditions appropriate for individual and population persistence. It should be considered a continuous variable, ranging from low to medium to high, based on resources available for survival, reproduction, and population persistence, respectively. Researchers commonly equate high-quality habitat with vegetative features that may contribute to the presence (or absence) of a species (e.g., Habitat Suitability Index models; Laymon and Barrett 1986, Morrison et al. 1991). We think, however, that quality should be explicitly linked with demographic features if it is to be a useful measure. For example, theoretical discussions of carrying capacity (Leopold 1933, Dasmann et al. 1973) have equated a high-quality habitat with one that has a density of animals in balance with its resources. In practice, this has been interpreted to mean that a high-quality habitat is one with large densities of animals (Laymon and Barrett 1986). However, Van Horne (1983) demonstrated that density is a misleading indicator of habitat quality, and those confirming source and sink habitats in nature (Pulliam 1988, Wootton and Bell 1992) have persuaded many ecologists to de-emphasize density. Thus, we propose that although carrying capacity can be equated with some level of habitat quality, habitat quality itself should not be based on numbers of organisms, but on demographics of individuals or populations.

Relatedly, the term "suitable" habitat should not be used because if an organism occupies an area that supports at least some of its needs, then it is habitat. So, by definition then, habitat is suitable. Thus, there is no such thing as unsuitable habitat, because it is the quality that changes, not the suitability *per se*. Terms such as "nonhabitat," especially when used to identify parts of a "home range" not used by an animal during a study, can be misleading. We caution that (1) home range is not necessarily equivalent to habitat (Burt 1943) and (2) unused portions of a home range in any given study may provide habitat for an animal at another time. We therefore think that it is appropriate to use "nonhabitat" in some instances, but with care.

We think that the terms "unused" or "unoccupied" habitat (and the converse of the terms) are appropriate when ecologists are discussing threatened, endangered, or rare species that are so reduced in numbers that they cannot use some areas of habitat, but would do so if their numbers were greater and they had the opportunity. Additionally, the term is appropriate when discussing species (of any abundance) that exploit patchy resources, where unused patches frequently occur, at least temporarily. "Unused" and "unoccupied" habitat are not synonymous with "nonhabitat."

We think that terms such as "macrohabitat" and "microhabitat" are relative and refer to the level (Johnson 1980) at which a study is being conducted for the animal in question. Thus macro- and microhabitat should be defined on a study-specific and species-specific basis. Generally, macrohabitat is used to refer to landscape-scale features such as seral stages or zones of specific vegetation associations (Block and Brennan 1993). This would usually equate to Johnson's (1980) first level ("order") of habitat selection. Microhabitat usually refers to finer-scaled habitat features, such as would be important in levels 2–4 in Johnson's (1980) hierarchy. Thus, it is appropriate to use micro- and macrohabitat in a relative sense, and the scales to which they apply should be stated explicitly.

Finally, "critical habitat" is used primarily as a legal term describing the physical or biological features essential to the conservation of a species, which may require special management considerations or protection (U.S. Fish and Wild. Serv. 1988). Critical habitat can occur in areas within or outside the geographic range of a species (Schreiner 1976, U.S. Fish and Wild. Serv. 1988). We think that this definition is not specific enough ecologically to allow for easy and rapid delineation of critical areas for threatened and endangered organisms, nor is it concrete enough to satisfy many parties concerned with U.S. Fish and Wildlife listing decisions (e.g., public interest groups and lawyers). Thus, we propose that critical habitat should be specifically linked with the concept of high-quality habitat, which equates to an area's ability to provide resources for population persistence; Murphy and Noon (1991) reached the same conclusion. This makes it an operational and ecological term rather than a political term.

We rated each paper (Table 2) according to how authors used habitat terms compared with our definitions and how consistently they used the terms in

the article. A rating of 1 ("correct") was assigned if a definition similar in intention to the definition we provided was given for the term and if the term was used consistently throughout the article. A rating of 4 ("incorrect") was given if none of these criteria were met. A rating of 2 ("weak") was given if no definition was provided or if the definition was incomplete, but the use of the term was similar to our standard definition. A rating of 3 ("poor") was given if no definition was provided and the use of the term fluctuated between being "correct" and "incorrect" in the same article.

Finally, we identified 3 terms—"abandoned," "unused," and "occupied" habitat—that were all rated as correct uses. The term abandoned was used correctly to refer to habitat that was no longer used by an endangered species in Arizona, and the term occupied was used correctly to refer to habitat still being used by threatened and rare species. Unused habitat was used to describe analyses of "used" versus "unused" areas within home ranges, and the authors (Clark et al. 1993) correctly stated that randomly selected "unused" areas often include used habitats.

Results

Of the 50 articles we reviewed, only 9 (18%) correctly defined and used terms related to habitat (Table 2). Of these 9 papers, 6 contained ≥2 habitat-related terms; of these, only 2 correctly defined and used all of the habitat-related terms in each paper. Of the 50 articles we reviewed, 47 used the term "habitat," and of these articles, habitat was defined and used correctly in only 5 of 47 papers (11%). It was used weakly or poorly (e.g., no definition was given and it was sometimes confused with a vegetation association) in 34 of 47 papers (72%), and it was used incorrectly (e.g., was not defined and was confused with a vegetation association) in 8 of 47 papers (17%).

The term most commonly used incorrectly was "habitat type." Of the 17 times it occurred, it was used incorrectly 16 times (94%) to refer to a vegetation association. In only 1 instance was the term used as it was first defined by Daubenmire (1968); we rated this as a correct use because of the reference to Daubenmire's original definition.

Another problem we identified was the failure to define a term except through the statistical analysis used to determine its presence or absence. For example, habitat use, selection, and availability were not defined conceptually in 23 of 28 papers (82%). However, in 7 instances the authors concluded that animals exhibited "use" or "selection" when there were significant *P*-values in tests of use versus measures of "availability." Habitat preference was used correctly only 2 of 6 times (33%) and weakly 4 times (67%).

We found several adjectives used to describe habitat quality: "high value," "less desirable," "unfavorable," "quality," "optimum," and "suitable" habitats. These were rated, collectively, as weak in 1 case (12.5%), poor in 6 cases (75%), and incorrect in 1 case (12.5%). We found only 1–2 references each for "critical habitat," "habitat structure," "microhabitat," and "macrohabitat." Collectively, use of these terms was rated as weak (50%), poor (25%), or incorrect (25%).

Discussion

Habitat terminology was used vaguely and imprecisely in the majority (82%) of articles we reviewed. Some may argue with us for ranking articles as "weak" if they did not provide complete definitions of terms. We counter this with several points. First, wildlife scientists have to use words correctly to communicate with each other. We think that there is a deep-seated problem in the ecological sciences: we use terms haphazardly, either without providing definitions, or providing definitions that are full of vague, non-operational terms. Fortunately, "habitat" and related terms are relatively straightforward to define. Unfortunately, other words in the literature (e.g., carrying capacity, community, ecosystem) are more difficult. Peters (1991:81–82) suggested that without clear, operational definitions, different users may develop inconsistent definitions. Each new author in each new paper redefines a term, definitions proliferate, and finally, authors present whatever definitions suit their own needs.

Second, we should consider the need for effective communication with scientists in other disciplines. There are large differences in how wildlife scientists, conservation biologists, plant ecologists, theoretical ecologists, and restoration ecologists use habitat-related words. The schism between so-called basic and applied sciences already runs deep; the misuse of ecological terms among scientists makes the chasm wider. There are many ecological problems to which we must jointly attend (Meffe and Carroll 1994); thus, we suggest that our terminology be tightened so that scientists can cooperate effectively to solve problems.

Finally, the recent increase in the number of scientists called to be expert witnesses at court hearings (Murphy and Noon 1991) troubles many ecologists. They wonder whether professionals in the natural sciences are capable of providing the definitive answers sought by lawyers. Controversies such as that over the northern spotted owl (*Strix occidentalis oc-*

cidentalis) have raised scientists' concerns about the accuracy of their data (Thomas et al. 1990); scientists should also worry about the accuracy of their terminology. If we cannot operationalize our concepts and theories, and use habitat terms consistently, then we cannot blame lawyers, the media, and the public for being confused by our ambiguities.

Recommendations

We recommend the following procedures to help alleviate problems in defining habitat-related and other terms:

1. Until scientists use habitat-related terms consistently, we should define habitat concepts in such a way as to address all of the points stressed earlier in this paper: i.e., words used in definitions should be measurable and accurate.
2. Authors should cite references to the first instance and use of terminology, or use a reference with definitions following the criteria we listed above. For example, Leopold (1933) first defined and discussed carrying capacity, but Leopold is seldom cited for coining the term. Authors discussing carrying capacity should therefore cite Leopold as the originator of the concept, and then present operational modifications of the concept if necessary.
3. Scientists must make a serious commitment to standardizing terminology. It will require us to learn definitions and to talk frankly with our peers about how to define nebulous terms. It will be worth the time and effort, however, because we will gain a terminology that is more science than art.

Acknowledgments. J. Heffelfinger and R. W. Mannan reviewed earlier drafts of the manuscript and made many helpful suggestions. Two anonymous reviewers provided us with further insightful suggestions, and the paper was also substantially improved by the comments of J. A. Wiens. This study was supported by the Wildlife and Fisheries Program, School of Renewable Natural Resources, University of Arizona, Tucson.

Literature cited

Adam, M. D., M. J. Lacki, and T. G. Barnes. 1994. Foraging areas and habitat use of the Virginia big-eared bat in Kentucky. J. Wildl. Manage. 58:462–469.

Allaby, M. 1992. The concise Oxford dictionary of zoology. Oxford Univ. Press, Oxford, U.K. 508pp.

Alverson, W. S., D. M. Waller, and S. L. Solheim. 1988. Forests too deer: edge effects in northern Wisconsin. Conserv. Biol. 2:348–355.

Anderson, S. H., and K. J. Gutzwiller. 1994. Habitat evaluation methods. Pages 592–606 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats, Fifth ed. The Wildl. Soc., Bethesda, Md.

Bell, S. S., E. D. McCoy, and H. R. Mushinsky. 1991. Habitat structure: the physical arrangement of objects in space. Chapman and Hall, London, U.K. 438pp.

Bellantoni, E. S., and P. R. Krausman. 1993. Habitat use by collared peccaries in an urban environment. Southwest. Nat. 38:345–351.

Bissonette, J. A., R. J. Frederickson, and B. J. Tucker. 1991. American marten: a case for landscape-level management. Pages 115–134 *in* J. E. Rodiek and E. G. Bolen, eds. Wildlife and habitats in managed landscapes. Island Press, Washington, D.C.

Block, W. M., and L. A. Brennan. 1993. The habitat concept in ornithology: theory and applications. Pages 35–91 *in* D. M. Power, ed. Current ornithology. Vol. 11. Plenum Press, New York, N.Y.

Boitani, L., L. Mattei, D. Nonis, and F. Corsi. 1994. Spatial and activity patterns of wild boars in Tuscany, Italy. J. Mammal. 75:600–612.

Bookhout, T. A. 1994. Research and management techniques for wildlife and habitats. Fifth ed. The Wildl. Soc., Bethesda, Md. 740pp.

Boyd, R. J., A. Y. Cooperrider, P. C. Lent, and J. A. Bailey. 1986. Ungulates. Pages 519–564 *in* A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart, eds. Inventory and monitoring of wildlife habitat. U.S. Dep. Inter., Bur. Land Manage. Serv. Cent., Denver, Colo.

Brown, R. L. 1994. Effects of timber management practices on elk. Ariz. Game and Fish Dep. Tech. Rep. 10. 70pp.

Brown, J. S., B. P. Kotler, and W. A. Mitchell. 1994. Foraging theory, patch use, and the structure of a Negev Desert granivore community. Ecology 75:2286–2300.

Bryant, F. C. 1991. Managed habitats for deer in juniper woodlands of western Texas. Pages 57–75 *in* J. E. Rodiek and E. G. Bolen, eds. Wildlife and habitats in managed landscapes. Island Press, Washington, D.C.

Burkett, D. W., and B. C. Thompson. 1994. Wildlife association with human-altered water sources in semiarid veg etation communities. Conserv. Biol. 8:682–690.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. J. Mammal. 24:346–352.

Butynski, T. M. 1990. Comparative ecology of blue monkeys (*Cercopithecus mitis*) in high- and low-density subpopulations. Ecol. Monogr. 60:1–26.

Clark, J. D., J. E. Dunn, and K. G. Smith. 1993. A multivariate model of female black bear habitat use for a geographic information system. J. Wildl. Manage. 57:519–526.

Cooperrider, A. Y., R. J. Boyd, and H. R. Stuart. 1986. Inventory and monitoring of wildlife habitat. U.S. Dep. Inter., Bur. Land Manage. Serv. Cent., Denver, Colo. 858pp.

Dasmann, R. F., J. P. Milton, and P. H. Freeman. 1973. Ecological principles for economic development. John Wiley and Sons, London, U.K. 252pp.

Daubenmire, R. 1968. Plant communities: a textbook of plant synecology. Harper and Row, New York, N.Y. 300pp.

Debinski, D. M., and P. F. Brussard. 1994. Using biodiversity data to assess species-habitat relationships in Glacier National Park, Montana. Ecol. Appl. 4:833–843.

Etchberger, R. C., P. R. Krausman, and R. Mazaika. 1989. Mountain sheep habitat characteristics in the Pusch Ridge Wilderness, Arizona. J. Wildl. Manage. 53:902–907.

FLEMING, T. H. 1991. The relationship between body size, diet, and habitat use in frugivorous bats, genus *Carollia* (Phyllostomidae). J. Mammal. 72:493-501.

FOWLER, C. W., AND T. D. SMITH. 1981. Dynamics of large mammal populations. John Wiley and Sons, New York, N.Y. 477pp.

FRANK, D. A., AND S. J. MCNAUGHTON. 1992. The ecology of plants, large mammalian herbivores, and drought in Yellowstone National Park. Ecology 73:2043-2058.

FRANKLIN, W. L., AND W. E. JOHNSON. 1994. Hand capture of newborn open-habitat ungulates: the South American guanaco. Wildl. Soc. Bull. 22:253-259.

GOLDSMITH, A. E. 1990. Vigilance behavior of pronghorns in different habitats. J. Mammal. 71:460-462.

GOULD, J. H., AND K. J. JENKINS. 1993. Seasonal use of conservation reserve program lands by white-tailed deer in east-central South Dakota. Wildl. Soc. Bull. 21:250-255.

GRINNELL, J. 1917. The niche-relationships of the California thrasher. Auk 34:427-433.

GYSEL, L. W., AND L. J. LYON. 1980. Habitat analysis and evaluation. Pages 305-327 *in* S. D. Schemnitz, ed. Wildlife management techniques manual, Fourth ed. The Wildl. Soc., Washington, D.C.

HUTCHINSON, G. E. 1957. Concluding remarks. Cold Spring Harbor Symp. on Quant. Biol. 22:415-427.

HUTTO, R. L. 1985. Habitat selection by nonbreeding, migratory land birds. Pages 455-476 *in* M. L. Cody, ed. Habitat selection in birds. Academic Press, Orlando, Fla.

IRWIN, L. L., J. G. COOK, D. E. MCWHIRTER, S. G. SMITH, AND E. B. ARNETT. 1993. Assessing winter dietary quality in bighorn sheep via fecal nitrogen. J. Wildl. Manage. 57:413-421.

JAKSIC, F. M., J. E. JIMENEZ, R. G. MEDEL, AND P. A. MARQUET. 1990. Habitat and diet of Darwin's fox (*Pseudalopex fulvipes*) on the Chilean mainland. J. Mammal. 71:246-248.

JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65-71.

KIE, J. G., V. C. BLEICH, A. L. MEDINA, J. O. YOAKUM, AND J. W. THOMAS. 1994. Managing rangelands for wildlife. Pages 663-688 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth ed. The Wildl. Soc., Bethesda, Md.

KISSELL, R. E., AND M. L. KENNEDY. 1992. Ecological relationships of co-occurring populations of opossums (*Didelphis virginiana*) and raccoons (*Procyon lotor*) in Tennessee. J. Mammal. 73:808-813.

KOEHLER, G. M., AND M. G. HORNOCKER. 1991. Seasonal resource use among mountain lions, bobcats, and coyotes. J. Mammal. 72:391-396.

KONDOLF, G. M. 1994. Livestock grazing and habitat for a threatened species: land-use decisions under scientific uncertainty in the White Mountains, California, USA. Environ. Manage. 18:501-509.

LAYMON, S. A, AND R. H. BARRETT. 1986. Developing and testing habitat-capability models: pitfalls and recommendations. Pages 87-91 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

LEOPOLD, A. 1933. Game management. Charles Scribner's Sons, New York, N.Y. 481pp.

LITVAITIS, J. A., K. TITUS, AND E. M. ANDERSON. 1994. Measuring vertebrate use of terrestrial habitats and foods. Pages 254-274 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth ed. The Wildl. Soc., Bethesda, Md.

MANNAN, R. W., R. N. CONNER, B. MARCOT, AND J. M. PEEK. 1994. Managing forestlands for wildlife. Pages 689-721 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. Fifth ed. The Wildl. Soc., Bethesda, Md.

MCCOY, E. D., AND S. S. BELL. 1991. Habitat structure: the evolution and diversification of a complex topic. Pages 3-27 *in* S. S. Bell, E. D. McCoy, and H. R. Mushinsky, eds. Habitat structure: the physical arrangement of objects in space. Chapman and Hall, New York, N.Y.

MEFFE, G. K., AND C. R. CARROLL. 1994. Principles of conservation biology. Sinauer Assoc., Sunderland, Mass. 600pp.

MORRISON, M. L., B. G. MARCOT, AND R. W. MANNAN. 1992. Wildlife-habitat relationships: concepts and applications. Univ. Wisconsin Press, Madison. 343pp.

MORRISON, M. L., T. TENNANT, AND T. A. SCOTT. 1994. Environmental auditing: laying the foundation for a comprehensive program of restoration for wildlife habitat in a riparian floodplain. Environ. Manage. 18:939-955.

MORRISON, M. L., W. M. BLOCK, AND J. VERNER. 1991. Wildlife-habitat relationships in California's oak woodlands: where do we go from here? Pages 105-109 *in* Proceedings of the symposium on California's oak woodlands and hardwood rangeland. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. PSW-126.

MURPHY, D. D. 1988. Challenges to biological diversity un urban areas. Pages 71-76 *in* E. O. Wilson and F. M. Peter, eds. Biodiversity. Natl. Acad. Press, Washington, D.C.

MURPHY, D. D., AND B. D. NOON. 1991. Coping with uncertainty in wildlife biology. J. Wildl. Manage. 55:773-782.

OCKENFELS, R. A., D. E. BROOKS, AND C. H. LEWIS. 1991. General ecology of Coues' white-tailed deer in the Santa Rita Mountains. Ariz. Game and Fish Dep. Tech. Rep. 6. 73pp.

ODUM, E. 1971. Fundamentals of ecology, Third ed. W. B. Saunders Co., Philadelphia, Pa. 574pp.

ORIANS, G. H. 1993. Endangered at what level? Ecol. Appl. 3:206-208.

PATTON, D. R. 1992. Wildlife habitat relationships in forested ecosystems. Timber Press, Portland, Oreg. 392pp.

PAULEY, G. R., J. M. PEEK, AND P. ZAGAR. 1993. Predicting white-tailed deer habitat use in northern Idaho. J. Wildl. Manage. 57:904-913.

PEEK, J. M. 1986. A review of wildlife management. Prentice-Hall, Englewood Cliffs, N.J. 486pp.

PETERS, R. H. 1991. A critique for ecology. Cambridge Univ. Press, Cambridge, U.K. 366pp.

PLUMB, G. E., AND J. L. DODD. 1993. Foraging ecology of bison and cattle on a mixed prairie: implications for natural area management. Ecol. Appl. 3:631-643.

PULLIAM, H. R. 1988. Sources, sinks, and population regulation. Am. Nat. 132:652-661.

RODIEK, J. E., AND E. G. BOLEN. 1991. Wildlife and habitats in managed landscapes. Island Press, Washington, D.C. 219pp.

ROMESBURG, H. C. 1981. Wildlife science: gaining reliable knowledge. J. Wildl. Manage. 45:293-313.

ROSENBERG, K. V., AND M. G. RAPHAEL. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. Pages 263-272 *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

SAMUEL, M. D., AND M. R. FULLER. 1994. Wildlife radiotelemetry. Pages 370-418 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats, Fifth ed. The Wildl. Soc., Bethesda, Md.

SCHEMNITZ, S. D., editor. 1980. Wildlife management techniques manual, Fourth ed. The Wildl. Soc., Bethesda, Md. 686pp.

SCHREINER, K. M. 1976. Critical habitat: what it is and is not. Endangered Species Tech. Bull. 1:1-4.

Smith, A. A., and R. W. Mannan. 1994. Distinguishing characteristics of Mt. Graham red squirrel midden sites. J. Wildl. Manage. 58:437–445.

Spowart, R. A., and F. B. Samson. 1986. Carnivores. Pages 475–496 *in* A. Y. Cooperrider, R. J. Boyd, and H. R. Stuart, eds. Inventory and monitoring of wildlife habitat. U.S. Dep. of Inter., Bur. Land Manage. Serv. Cent., Denver, Colo.

Tershy, B. R. 1992. Body size, diet, habitat use, and social behavior of *Balaenoptera* whales in the Gulf of California. J. Mammal. 73:477–486.

Thomas, J. W., E. D. Forsman, J. B. Lint, E. C. Meslow, B. R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. U.S. Gov. Printing Off., Washington, D.C.

U.S. Department of Agriculture. 1992. Coronado National Forest Plan. U.S. Gov. Printing Off., Washington, D.C. 130pp.

U.S. Fish and Wildlife Service. 1988. Endangered species act of 1973, as amended through the 100th Congress. U.S. Dep. Inter., Washington, D.C.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47:893–901.

Verner, J., M. L. Morrison, and C. J. Ralph. 1986. Introduction. Pages xi–xv *in* J. Verner, M. L. Morrison, and C. J. Ralph, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Univ. Wisconsin Press, Madison.

Wecker, S. C. 1964. Habitat selection. Sci. Am. 211:109–116.

Weckerly, F. W. 1992. Territoriality in North American deer: a call for a common definition. Wildl. Soc. Bull. 20:228–231.

White, P. J., and K. Ralls. 1993. Reproduction and spacing patterns of kit foxes relative to changing prey availability. J. Wildl. Manage. 57:861–867.

Wielgus, R. B., and F. L. Bunnell. 1994. Sexual segregation and female grizzly bear avoidance of males. J. Wildl. Manage. 58:405–413.

Wiens, J. A. 1972. Anuran habitat selection: early experience and substrate selection in *Rana cascadae* tadpoles. Anim. Behav. 20:218–220.

Wiens, J. A. 1981. Scale problems in avian censusing. Stud. Avian Biol. 6:513–521.

Wiens, J. A. 1984. Resource systems, populations, and communities. Pages 397–436 *in* P. W. Price, C. N. Slobodchikoff, and W. S. Gaud, eds. A new ecology: novel approaches to interactive systems. John Wiley and Sons, New York, N.Y.

Wiens, J. A. 1989. Spatial scaling in ecology. Functional Ecol. 3:385–397.

Wilson, E. O., and F. M. Peter. 1988. Biodiversity. Natl. Acad. Press, Washington, D.C. 521pp.

Wootton, J. T., and D. A. Bell. 1992. A metapopulation model of the peregrine falcon in California: viability and management strategies. Ecol. Appl. 2:307–321.

Yoakum, J., W. P. Dasmann, H. R. Sanderson, C. M. Nixon, and H. S. Crawford. 1980. Habitat improvement techniques. Pages 329–403 *in* S. D. Schemnitz, ed. Wildlife management techniques manual. Fourth ed. The Wildl. Soc., Washington, D.C.

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